Poppy: a New Bio-Inspired Humanoid Robot Platform for Biped Locomotion and Physical Human-Robot Interaction

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1 Introduction

Humanoid robots are predicted to play a key role in our everyday lives in the future. Yet, several challenges need to be addressed before this becomes a reality. In particular, biped robots need to be able to locomote robustly in human environments, which includes the ability to keep stability when unpredictable physical contact with humans happens. At the same time, these robots need to be capable of rich and safe social and physical interaction with humans, and to adapt to the behaviour and preferences of each particular user.

We should not only try to solve these challenges through artificial cognitive intelligence but also through body intelligence [1]. On one hand, a way to permit robots to adapt their behaviors to unknown environments is to provide them with learning algorithms based on social guidance [2], or on autonomous self-exploration mechanisms [3, 4]. On the other hand, a part of the computation needed for such adaptation could also be done through the intrinsic mechanics and electronics of the robot, thus providing effective and hyper-responsive reactions while simplifying the algorithms of the different behaviors. Actually, body intelligence, realizing morphological computation, has been argued to facilitate and guide considerably the learning and development of sensorimotor skills [5].

No current platform (Nao [6], Darwin Op [7], Nimbro Op [8], HRP-2, ...) does offer both a bio-inspired morphology optimized for both walking and human physical interaction capability (safe, compliant, playful). To address these challenges, while exploring further approaches to the one elaborated for the Acroban robot [9], we have designed a new bio-inspired humanoid robotic platform, called Poppy, which provides some of the software and hardware features needed to explore physical and social interaction together with biped locomotion for personal robots. It presents the following main features:

- Design inspired from the study of the anatomy of the human body and its bio-mechanic, with an emphasis on leg structure;
- Dynamic and reactive: we try to keep the weight of the robot as low as possible (optimized geometry of the pieces and smaller motors);
- Human interaction: screen for communication and compliant physical interaction;
- Practical platform: low cost, ease of use and easy to reproduce through rapid prototyping techniques;

2 Poppy

Poppy (Figure 1) is a humanoid robot, 84cm tall, and 3 kg. It has a large sensorimotor space including 25 Robotix motors (including MX-28 permitting dynamic compliance control), force sensors under its feet and some extra sensors in the head: 2 HD-wide angle-cameras, a stereo-micro and an inertial central unit (IMU 9DoF) plus a large LCD Screen (4 inch) for visual communication (e.g. emotions, instructions or debug).

The poppy morphology is designed based on important aspects of the actual human body. This inspiration is expressed in the whole structure (e.g. the limb proportions) and in particular in the trunk and legs. The weight of all limbs has been minimized thanks to sophisticated girder like design, which was made possible by the use of 3D printing techniques (all limbs were 3D printed).

Poppy uses the bio-inspired trunk system introduced by Acroban[9]. These five motors allow it to reproduce the main DOFs of the human spine [10]. This feature allows the integration of more natural and fluid motion while improving the user experience during physical interactions. In addition, the spine plays a fundamental role in bipedal walking and postural balance by actively participating in the balancing of the robot.

The legs were designed to increase the stability and agility of the robot during the biped walking by combining bio-inspired, semi-passive, lightweight and mechanical-computation features.The architecture of the hips and thighs of Poppy uses biomechanical principles existing in humans. The human femur is actually slightly bent at an angle of about 6 degrees. In addition, the implantation of the femoral head in the hip is on the side. This results in a reduction of the lateral hip movement needed to move the center of gravity from one foot to another and a decrease in the lateral falling speed. In the case of Poppy, the inclination of its thighs by an angle of 6 degrees causes a gain of performance of more than 30% for the two above mentioned points. Another example is Poppy's feet. Poppy has the particularity of

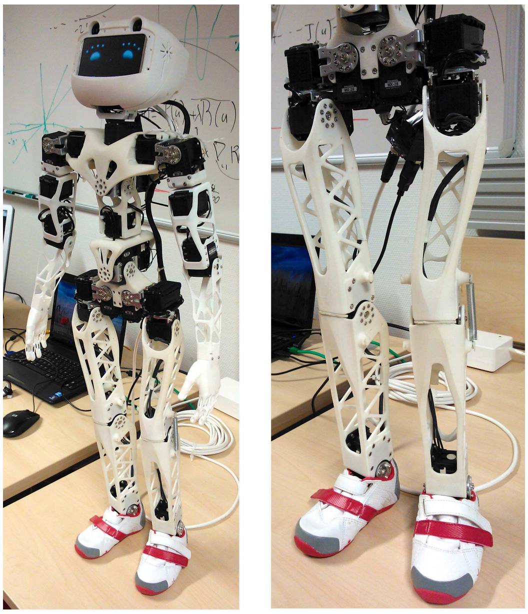

Figure 1: a. Global view of the Poppy platform. b. Zoom on legs design

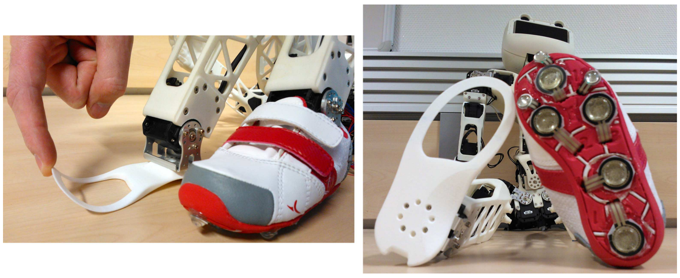

Figure 2: Poppy feet use actual children shoes combine with a compliant feet, toes (a.) and pressure sensors (b.)

having small feet compared to standard humanoids. It has humanly proportioned feet (ie about 15% of its total size). It is also equipped with toe joint actuated by compliance (see Figure 2.a). We believe that these are two key features to obtain a human-like and efficient walking gait. However, that raises problems regarding balance because the support polygon is reduced. We included pressure sensors under each foot in order to get accurate feedback of the current state of the robot (see Figure 2.b).

3 Open questions

In our current work, we explore the combination of both a bio-inspired body and bio-inspired learning algorithms. We are currently working on experiments involving Poppy to perform skill learning. First we aim at achieving an effective postural balance using the articulated spine, the feet pressure sensors and the IMU. Then, when this is learnt and used as a building block, we will experiment on the learning of biped walking usingonline and developmental learning algorithms such as [4] and [11]. We are expecting to clearly reduce the learning time needed and increase the quality of the learned skills thanks to the bio-inspired morphology of Poppy.

We are also studying social physical interactions with non-expert users. We plan to conduct user studies to evaluate how playful physical interactions and emotions could improve learning in robotics. We think that the poppy platform could be very suitable for such studies.

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